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Validation of the Wind Erosion Stochastic Simulator (WESS) and the Revised Wind Erosion Equation (RWEQ) for Single Events

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Introduction

The Environmental Policy Integrated Climate model (EPIC) has been used to evaluate policy effects on soil erosion. Recently, WESS, the wind erosion submodel of EPIC,was successfully evaluated against observed estimates of erosion from a clay loam soil for several wind events in Alberta, Canada (Potter, et al., 1998). This study was conducted for a single season and surface roughness and vegetative cover did not vary sufficiently during the period of investigation to assess the effectiveness of the model under soil surface conditions other than those noted.

USDA Agricultural Research Service (ARS) scientists and engineers have recently released RWEQ ((http://www.csrl.ars.usda.gov/wewc/rweq/readme.htm). RWEQ makes annual or period estimates of wind erosion based on a single event wind erosion model that includes factors for wind and rainfall, soil roughness, the erodible fraction of soil, crusting, and surface residues (Fryrear et al., 1998a, 1998b). A previous test of 11 wind erosion events found the correlation between observed and estimate maximum transport (Qmax) and field soil loss (SL) to be 0.82 and 0.97, respectively (Fryrear et al., 1998a).

Wind erosion modeling efforts conducted by the ARS over the last decade have necessitated the collection of several large bodies of wind erosion and weather data from many diverse locations in the United States. This effort has been facilitated by the development of technology and equipment that have enabled the measurement of wind erosion losses on storm event basis (Fryrear, 1986; Stout and Zobeck, 1996). The availability of field measurements has improved the description of erosion losses across a field (Stout, 1990) and also permits the validation of wind erosion models. We tested RWEQ and WESS against much of the aforementioned body of data in order to determine the accuracy of their predictions.

Methods

Seven sites from six states across the United States were chosen to validate RWEQ. Individual storm event data at Big Spring, Texas (24 storms during 7 years of data collection) were used to validate WESS. The sites were described, instrumented, and the erosion data collected by USDA-ARS and USDA-NRCS personnel. All the sites were a 100 m radius circular field (~ 2.5 ha) outfitted with a weather station and 13 erosion sampling stations (Fryrear et al., 1998b). Weather data collected included 2 m wind speed and direction at one minute intervals. For the purpose of validating WESS and RWEQ, these wind data were averaged over 10 minute intervals. Soil surface condition data including ridge height, random roughness, percent erodible fraction, and standing and flat plant residues were collected several times during the data collection season.

Soil saltation and suspension loads at each of the 13 field locations were estimated by taking the weight of sediment collected in individual samplers at those locations and calculating the transport load (Fryrear and Saleh, 1993). Creep load was estimated for each of the 13 locations in a similar manner based upon transported soil weights collected at 4 locations in the field. Field soil loss for each event was calculated using soil transport estimates from selected locations across the field. Since all these field erosion observations are calculated estimates based upon actual measured observations, we will refer to the erosion data as observed estimates.

WESS simulations were run for the dates of 24 storm events in the seven years of erosion observations at Big Spring, TX. The period between field sampler servicing was rounded to the nearest multiple whole day and the 10 minute average wind data for that event was input along with the soil surface conditions reported for the site on that date. Soil roughness was calculated according to Potter and Zobeck (1990) when pin roughness data were available and were estimated by comparing chain roughness data (Saleh, 1993) with surface photographs when only chain roughness data were available. Initial soil moisture conditions were inferred from rainfall and temperature data for each event. The simulations for each event were run at distances from protected surface (DPS) that coincided most closely with the DPS of field samplers as these distances varied with the mean wind direction of each event.

RWEQ simulations were run for 41 storm events at six locations across the United States. RWEQ uses a number of input factors to estimate Qmax and SL. The wind factor (WF), erodible fraction (EF), surface crust factor (SCF), roughness (K'), and crop on the ground factor (COG) were determined for each erosion event. Details of the procedures to determine these values are described by Fryrear et al. (1998a, 1998b). The WF for each estimated storm was computed from one minute wind speed measurements averaged for the entire 24 hour day (Fryrear et al., 1998a). EF was determined for each location by dry sieving surface soil samples (Chepil, 1962). SCF was defined as a function of percent clay and organic matter (OM) content. K' was determined using measured roughness parameters and the amount of flat and standing residue were used to estimate COG (Fryrear et al., 1998b). Since the EF, K' and COG factors were often measured only two or three times per season, estimates of these factors were often necessary. Degradation of aggregates and roughness were estimated using cumulative rainfall and linear interpolation between measurement dates was used to estimate COG.

Results and Discussion

WESS was used to predict the erosion resulting from 24 of the individual wind events at Big Spring, TX during the seven years that wind erosion data was collected at this location. Erosion estimates using WESS under-predicted 9 events, accurately predicted 8 events, and over-predicted 7 events. In general, the events that WESS under-predicted were large magnitude storms with observed erosion estimates >1.0 kg m^{-2} and the events that WESS over-predicted were small storms with observed estimates < 0.2 kg m^{-2}. WESS gave the most accurate predictions for events that had observed estimated erosion from 0.2 kg m^{-2} to 1.0 kg m^{-2}. Since the large magnitude storms, some of which had observed estimates of greater than 5.0 kg m^{-2} at distances greater than 60 m from protected surface, have a much larger effect on annual erosion than the small storms, it is evident that WESS would tend to under-predict erosion on a annual basis.

Plots of the comparisons between WESS predicted erosion and observed estimated erosion for 4 events at Big Spring, TX are presented in Figure 1. The plot for the 4/22/89 event shows paired estimates with low variability and the relatively high accuracy of prediction for this event. The plot

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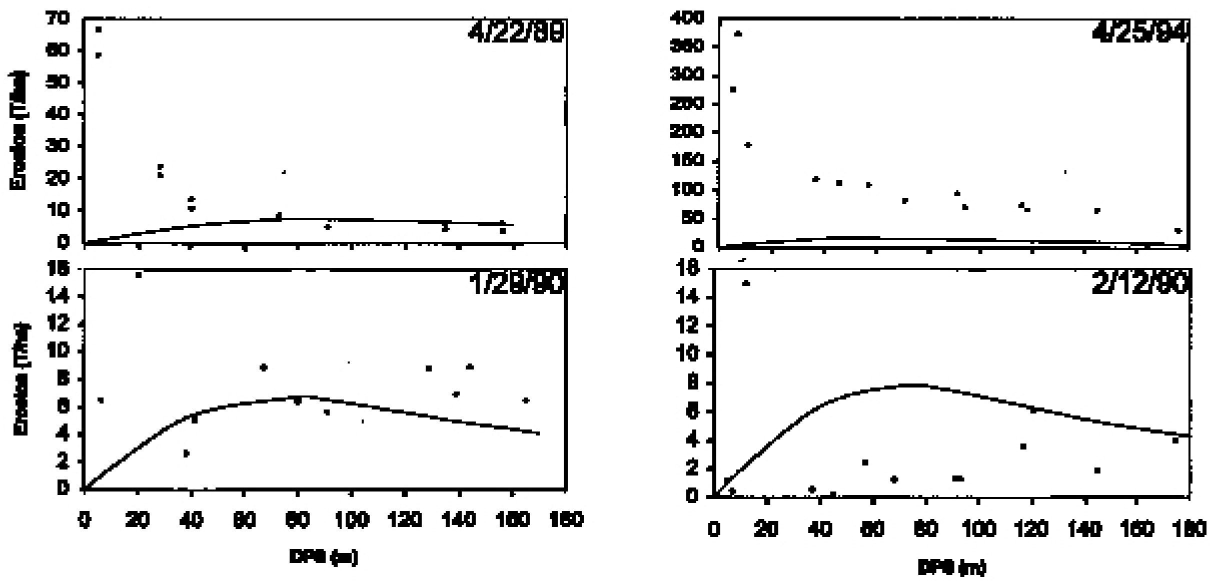

Figure 1. Plots of WESS predicted (solid lines) vs. observed estimated erosion (diamonds) by distance from protected surface (DPS) for four selected storm events at Big Spring, TX.

For the 4/25/94 event shows observed estimates with low variability and the typical under-prediction for large events. Both of these plots show the inability of WESS to accurately predict erosion rates at DPS of less than 60 m. Although this source of error would become increasingly insignificant as field size increases, it does point out a problem either with the use of transport load to estimate erosion rates or with the form of the equation used by this and other models to predict the erosion rate. This problem is worthy of further investigation.

Plots for the 1/29/90 and 2/12/90 events demonstrate another problem with prediction of wind erosion. These two events occurred 14 days apart, there was no rain or other change in surface conditions between the events, the wind speed and duration were nearly identical, WESS predicted similar erosion curves, and yet there is a great difference in the observed estimated erosion. There was a 150° shift in wind direction between the storms, but this was a circular field in a broad open area. In spite of the sophistication of our data collection and predictive models, there are probably sources of variability in any field that we may not ever be able to quantify and predict.

In general, RWEQ underestimated Qmax and SL. Close inspection of the data by location revealed that the estimates were not consistently higher or lower for most of the locations. Observed estimates for Qmax and SL were higher than RWEQ predictions in about 58% of the cases investigated. while observed estimates for S were higher than RWEQ predictions in only 22% of the events analyzed.

Simple linear regressions of observed estimates vs. RWEQ predictions of Qmax and SL revealed significant ($P<0.05$) correlations for Qmax and SL with correlation coefficients of 0.70 and 0.62, respectively. Figure 2 illustrates the relationship of the observed estimates and RWEQ predictions of Qmax for all storm events investigated. The relation of observed estimates and RWEQ predictions of SL is presented in Figure 3.

The results of the investigation with RWEQ are very encouraging. Erosion was measured at locations that varied considerably with respect to soil, climate, and wind patterns and yet the RWEQ predictions were correlated within an order of magnitude of the observed estimates.

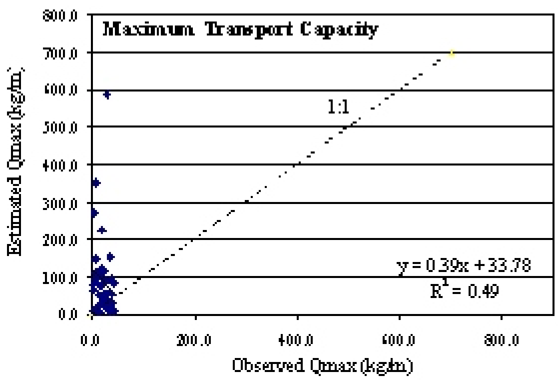

Figure 2. Relation of observed estimated and RWEQ predicted Qmax for 41 wind erosion events.

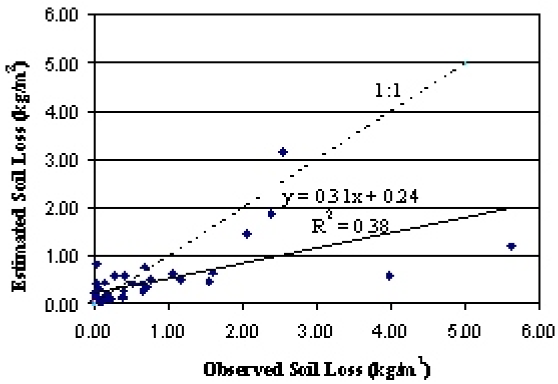

Figure 3. Relation of observed estimated and RWEQ predicted SL for 41 wind erosion events.

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